te technical note techn

Air Traffic Controller Memory A Field Survey

Earl S. Stein, Ph.D

March 1991

DOT/FAA/CT-TN90/60

U.S. Department of Transportation
Federal Aviation Administration

Technical Center
Atlantic City International Airport, N.J. 08405

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT/FAA/CT-TN90/60		

4. Title and Subtitle	5. Report Date
Air Traffic Control Memory - A Field Survey	March 1991
	6. Performing Organization Code: ACD-340
7. Author(s): Earl S. Stein Ph. D.	8. Performing Organization Report No.: DOT/FAA/CT-TN90/60
9. Performing Organization Name and Address: Federal Aviation Administration, Technical Center, Concepts Analysis Division, Atlantic City International Airport, N.J. 08405	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Federal Aviation Administration, Technical Center, Concepts Analysis Division, Atlantic City International Airport, N.J. 08405	13. Type of Report and Period Covered: Technical Note, Jan 1990-Jan 1991
	14. Sponsoring Agency Code: ACD-300

15. Supplementary Notes

16. Abstract

This current study had two goals. First was a need to evaluate the Controller Memory Handbook using input from current field controllers. The second goal was to gather data from field facilities concerning the impact of memory on the performance of controllers and how they went about trying to manage their memory resources in daily operations.

Controllers agreed that memory was an important element of their work. They were able to rate it independently of their evaluation of the Handbook. The average ratings on the Handbook for relevance, realism, and overall quality exceeded 7 on a 10-point scale. The majority of the respondents liked the Controller Memory Handbook and saw it as a positive contribution.

An open ended question asked for techniques that the controllers used to manage their limited memory resources. The responses covered a wide range of alternatives, but the most frequently cited techniques could be summarized by two words: "good housekeeping." Most controllers, who responded, suggested that effective memory management involved practicing what they were taught and using the tools they were provided in a consistant and conscientious manner.

17. Key Words	18. Distribution Statement
Air Traffic Control Memory Memory Enhancement Survey Control Techniques Memory Lapse	This document is available to the U.S. public through the National Technical Information Service Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	50	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

ACKNOWLEDGEMENTS

This work could not have been accomplished if there had been no Controller Memory Handbook. There would have been no handbook without the skill, expertise and motivation of Mr. Jim Bailey, Supervisory Air Traffic Controller from Huntsville Tower. Mr. Bailey has a rare combination of talents including an indepth knowledge of the air traffic control system and the artistic ability to develop complex ideas into graphic art that stands on its own. Appreciation is also due to Mr. Lloyd Alley, Facility Manager at Huntsville, who was very flexible in loaning Mr. Bailey's time for this project.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

EXECUTIVE SUMMARY

The controller memory handbook was developed in response to an Federal Aviation Administration(FAA) administrator's task force on controller operational errors. The task force identified two critical issues leading to errors: visual scanning and memory lapses. The handbook was created as part of program at the FAA Technical Center to provide controllers with some immediate assistance in today's control environment.

This current study had two goals. First was a need to evaluate the handbook using input from current field controllers. The second goal was to gather data from the field facilities concerning the impact of memory on the performance of controllers and how they went about trying to manage their memory resources in daily operations.

Enough handbooks were printed so that at least 10 could be sent to all the enroute centers and to a selected number of towers and terminal radar facilities(TRACONS). In all, 550 questionnaires were distributed. The return rate of 299 questionnaires or 54.36 percent was considerably higher than what might have been expected from a mail away survey. Twelve centers and 36 towers and/or tracons participated. Responding controllers covered a wide range of experience from 1 to 39 years with an average of 14.11 years. There were no significant differences between center and tower/TRACON controllers in terms of their ratings of the importance of memory or the quality of the handbook.

Controllers agreed that memory was an important element of their work. They were able to rate it independently of their evaluation of the handbook. The average ratings on the handbook for relevance, realism, and overall quality exceeded 7 on a 10-point scale. The majority of the respondents liked the Controller Memory Handbook and saw it as a positive contribution.

There were two questions in the survey which allowed the controller to write in answers. The first asked for information concerning the impact of memory on air traffic control(ATC). Most respondents interpreted this to mean what factors influenced their memories and performance. Those that they identified are seen frequently in other literature. They included: coordination, attention, distraction, fatigue, change, position relief briefings, overload, etc. Responses to this question indicated a considerable overlap in controllers thinking concerning memory and performance.

The second open ended question asked for techniques that the controllers used to manage their limited memory resources. The responses covered a wide range of alternatives, but the most frequently cited techniques could be summarized by two words: "**good housekeeping.**" Most controllers, who responded, suggested

that effective memory management involved practicing what they were taught and using the tools they were provided in a consistent and conscientious manner. There were no magic bullets. Given the current level of technology, they are basically saying that they already have what they need if it is used properly.

PROLOGUE

In today's world of modern high technology, many products are generated for the operators which may or may not take into consideration their needs and concerns. The Controller Memory Handbook was developed for controllers using today's technology. This was accomplished in order to help them make use of what tools they had already. The work involved the support and consulting of current and retired controllers. The handbook co-author is a current supervisory controller.

This survey was an effort to determine directly whether or not the handbook was, for lack of a better term, on the money. It was sent to the field with an accompanying questionnaire and no pre-conceptions. A second goal of this survey effort was to collect information from controller respondents concerning their views on the impact of memory in Air Traffic Control(ATC) and how they went about dealing with it. The background, scope, methods, and results of this survey are what follows.

INTRODUCTION

Background.

Memory is one of a number of elusive constructs within the human performance equation. It can never be observed directly and must be inferred based on the environmental cues and the behavior of the individual operator. The Federal Aviation Administration(FAA) has become increasingly concerned about actual and potential operational errors of air traffic controllers. The ATC system is highly complex and very dynamic. As new hardware and software systems are developed , it is essential that we establish a clear understanding of how controller memory will be influenced. Each controller is exposed to a virtual river of information which flows through their work stations at a pace that they cannot completely control (Sperandio, 1971; Kirchner and Laurig,1971;Thomas,1985). In order to manage the airspace within his/her domain, a certain amount of this information must be captured and retained primarily for tactical (3 to 5 minutes) use and secondarily for strategic planning, which is a concept still in its infancy for ATC. Human operators are limited in terms of the volume and speed of information they can process (Finklman and Kirchner, 1980; Spettel and Liebert, 1986; Warm and Dember, 1986).

Given current technology, the human operator must learn and retain critical information or must establish a strategy for obtaining what is needed in the here and now. It is likely that the complexity and number of strategies employed can have a major impact on job performance (Rasmussen, 1988). Failure to store, search, and/or retrieve key elements of operational data can lead

to inaccuracies of detection and/or decisions with resulting errors in the clearances issued. To date, there is no clear documentation concerning the memory demands placed upon controllers in their daily activities. This may well become even more confusing as new Advanced Automation Systems(AAS) come on line.

Controlling aircraft in today's crowded skies is a complex and dynamic process. Air traffic controllers are surrounded by sources of information from which they must select critical data. They code and store in their memories a portion of this data. However, they do not always do this effectively. One of the most common expressions uttered by controllers who have made an operational error is: "I forgot!" In the spring of 1987, an FAA operational error task group identified memory enhancement as an important area which could potentially decrease the frequency of errors (Operational Error Analysis Work Group, 1987). The Federal Air Surgeon approved a program directive with the Technical Center in May 1988. This led to an effort to make maximum use of what is currently known about human memory. This involved the identification of a set of basic principles, from which the Controller Memory Handbook or training aide was developed.

OVERVIEW.

Human memory is one of the oldest areas of research psychology to be systematically studied. There is a body of general literature which has been based on controlled laboratory experiments. There is much less available which focuses on the resolution of specific applied problems. There is also a "How to" literature which purports to be everything to everyone and suggests from the self-help counters of bookstores that the "real answers" are contained within the covers of the neatly shelved books. Somewhere within the scientific and the self-help literature, it was hoped there were basic concepts which could be drawn out and put into a form that might help air traffic controllers make fewer errors based on the misuse of their memories. It was assumed that controllers have a good grounding in their professional skills and that they possess the information they should have committed to the long term memory through their training and experience. Of primary concern here was the storage and recall of transient, dynamic information which develops, is used or misused, and then is discarded like a flight strip thrown into the box at the controllers feet.

SCOPE.

Very little knowledge is available regarding the impact of memory on the operators of high technology systems. This project has focused primarily on short term or tactical memory. Controllers using current technology generally operate within a tactical

window of 3 to 5 minutes. They acquire, code, and retain only what they need for that time period. New technology may influence this window and, by doing so, may have an impact on how memory is used in the future.

As long as there are human operators in the loop, there will be some need for them to store, retain, and retrieve a finite amount of information. The more that we can help them to effectively manage the flow of this data, the more productive they are likely to be. A theme of this project is that human beings are not terribly efficient at cataloging and storing large volumes of data. There are well known processes which work against them especially in a time-pressured environment. This project will not generate all the answers. It focuses on what we can do in today's system to help controllers reduce errors and the "I forgot" response.

HANDBOOK DEVELOPMENT.

The method employed involved reviewing a number of texts and one self-help book, looking for the basics of memory literature which might apply. This was coupled with field trips to a several terminal radar control facilities(TRACONS). The result was an initial list of what appeared to be 21 principles of learning/memory. Further inspection of this list indicated a certain amount of redundancy and also some concepts which we are not yet ready to try and relate to ATC. An example of this was the concept of "Positive transfer". When you have already learned something, it can be used to learn or relearn something new but similar. This is a very well known principle, but more thought will have to be invested to determine whether it is applicable to the types of tactical short term memory within this project. Given a reduced first cut list of principles, the analyst made some estimates of how the concepts might be illustrated. This required some additional help from controllers and from someone with an artistic sense, who could formulate the real pictures. It was fortunate that we were able to find these skills in the same person, the handbook co-author, Jim Bailey, SATCS, from the Huntsville Tower.

PRELIMINARY SUMMARY.

This section is titled "preliminary" because we are a long way from final definitive answers. However, there are a few observations which are appropriate from the initial literature review.

First and foremost is the growing certainty that **there is simply no one magic bullet to solve all the problems attributed to memory lapses**. This is probably no surprise to anyone. Also based on a very limited sample, it appears that self-help books (i.e., Lorrain and Lucas, 1974) will probably not be much help.

They tend to be geared towards either an academic or everyday framework rather than on the highly dynamic environment with which we are concerned. Further, contractors offering the final solution should be handled with a great deal of care and not necessarily be accepted at face value. Secondly, it is not all that clear that errors that controllers suggest are due to memory are, in fact, a result of memory, although memory is often a component of the chain of events leading to a problem.

An examination of the literature uncovered themes about planning and not overextending a human's resources. They suggest directly that controllers should not try to hold information in memory that they could arrange to get from some place else, such as flight strips appropriately marked or a note pad. Most if not all facilities have published procedures which encourage or require such activities, but are not universally followed. To quote a very senior controller (34 years) from the Atlanta Tower, many of the answers concerning memory lapses may well be resolved by consistent "good work habits." To quote a popular song "Know when to hold, and know when to fold." It is likely that there are strategies currently in use by effective controllers but not disseminated to the controller population, at large, which might help controllers plan and organize their physical and physiological resources so that fewer errors will occur. What we need to do is find them. In the interim, the development of the Controller Memory Handbook was meant to catch controllers attention and perhaps cause them to think a little about how well they are doing with what they have.

SURVEY METHOD

PARTICIPANTS.

In the old days of human research, people who participated in a study regardless of the nature of the work, were referred to as "subjects." This implied passivity and, to a certain extent, the role of the researcher or investigator was seen as all powerful. Participants in this survey were considered essential and active members of the study. The goal was to gather input from people who were currently on the boards and were faced with memory issues on a day to day basis. However, it was decided to accept input from any control personnel in the system who cared enough to respond. Sampling decisions had to be made since it was not feasible to send out handbooks and questionnaires to all the controllers in the field.

We elected to sample all 20 centers and a selected sample of levels 3-5 TRACONS/towers. It was believed that this would provide the largest return rate from facilities where memory demands were the greatest. Towers/TRACONS were chosen based on attempt to spread the geographic representation across the country. In addition to these facilities, copies of the Handbook

(Stein and Bailey, 1989), which was published as an FAA Technical note, and questionnaire were sent to the FAA Academy, the Center for Management Development (CMD) and FAA Headquarters. This will explain why there were some responses from controllers at level 1 and 2 facilities. These were primarily from students at CMD.

PROCEDURE.

For each sampled facility, the procedure was the same. The handbooks and questionnaires were sent though the facility manager along with a cover letter, which is included in appendix A. The letter described the program goals and what was intended by the field survey. The manager was asked to obtain voluntary input from controllers on the handbook and send it directly back to the FAA Technical Center. There was an offer of facility feedback for any manger that requested it. It amounted to a data summary of the responses without identification of the respondents. Most facilities returned one or more questionnaires. In two cases they ran off more copies and sent them back along with those that we sent them.

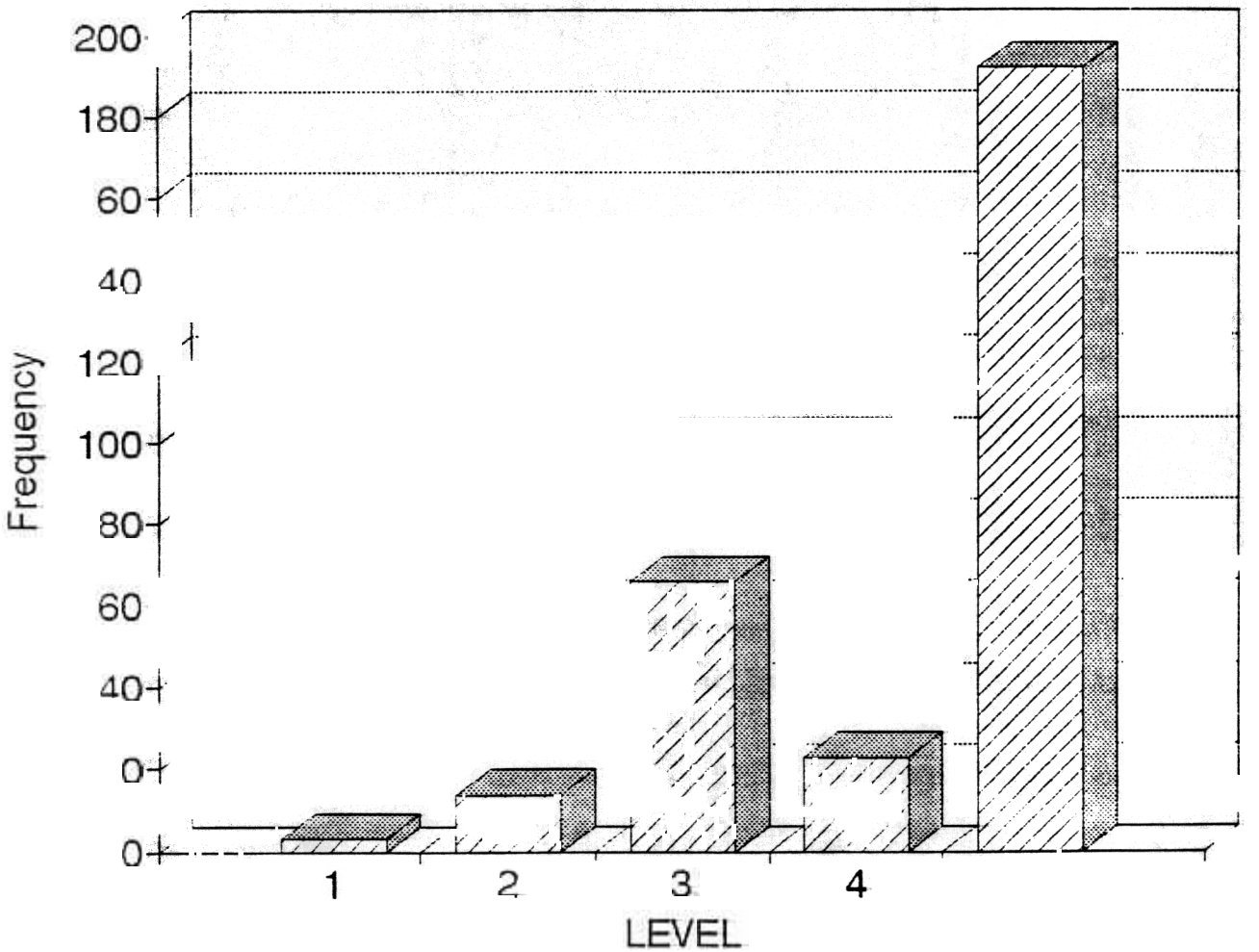
No telephonic or mail follow up was attempted for facilities that did not respond. This was done by intention to determine the degree to which there was interest in memory as an issue in ATC.

The questionnaire sent out with a sample of the handbooks was designed for simplicity, ease, and speed of self-administration. It was estimated that completion time would not exceed 15 minutes (see copy in appendix B). It was organized into sections which were not physically separated. The first section was a paragraph of general instruction followed on the first page by the second section of background or demographic items. Next were three bipolar 10-point scales. The fourth section had two open ended questions. The fifth included a bipolar overall evaluation of the handbook and an item which requested the respondents expression of interest in receiving more copies. Finally there was a block of close out instructions and a phone number for further information.

RESULTS

PARTICIPANTS.

There were 550 questionnaires sent out, and 299 were returned completed. This represented a return rate of 54.36 percent which is considered relatively high for a mail survey. Respondents included one or more people from 12 centers , 36 towers/TRACONS, CMD,and the FAA academy. Figure 1 represents a breakdown of controllers by the level of the facility they were from. The majority came from level 5 operations (chi square= 40.46, $P < .01$). Figure 2 summarizes the status of the respondents from



ART ANT .ITY EVEL.

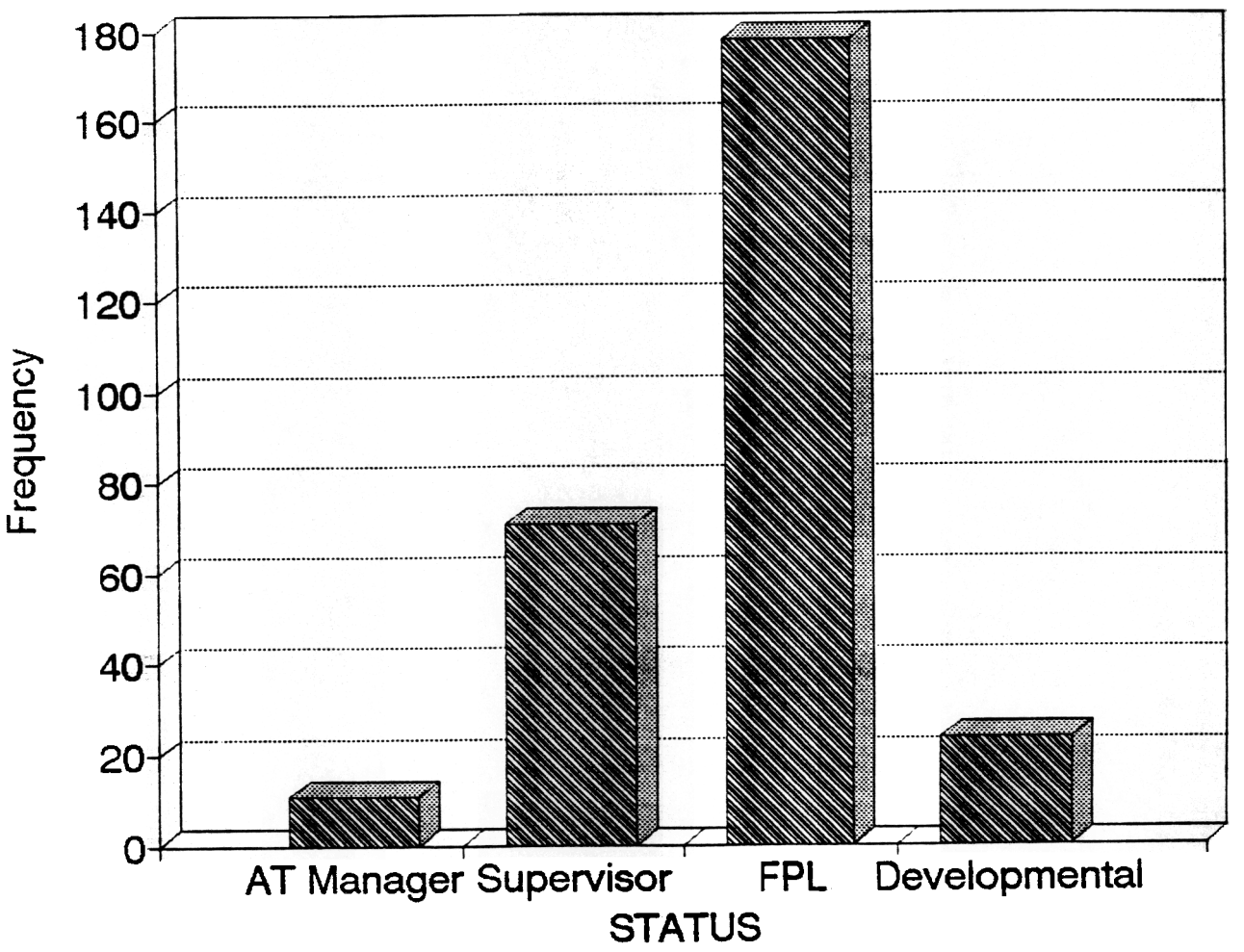


FIGURE 2. PARTICIPANT CONTROLLER STATUS

The majority of respondents were full performance level controllers.

Respondent position was coded for data analysis as follows: facility manager (1), other managers (2), full performance level controllers (3), and developmentals (4). It will be noted that these data do not add to 299, because some respondents chose to leave personal information questions blank. Of the 299 who elected to send in the questionnaire, only 10 chose to remain anonymous.

Participant experience ranged from a minimum of 1 year to a maximum of 39 years in ATC. The mean for the total sample was 14.14 years with a standard deviation of 10.01. There was no difference between the years of experience for respondents from centers (mean 14.11 years) and those from towers/TRACONS (mean 14.17).

DATA MANAGEMENT.

While the questionnaire was only two pages in length, it was possible to generate a considerable amount of information given the high return rate. Two classes of spread sheets were established using Quattro-Pro software. The first class was set up to organize the numerical data into a data base for initial descriptive study and for latter transfer to a more comprehensive statistical package - the Complete Statistical System (CSS). The second class was created to deal with the text responses to the two open ended questions which asked respondents to look beyond the handbook for an overview of how memory had impacted their work and how they went about coping with it. These data were put into a spreadsheet for sorting and later import into a word processor for editing and subsequent printing. All responses are reproduced in appendix C of this report.

The numerical data were entered into the spreadsheet as the responses were mailed in. The text material was not entered until all responses had arrived. While in many cases people who respond to questionnaires tend to leave open ended text questions blank, in this study most took the time to answer. Of 299 responses, 211 controllers answered one or both of these questions. The majority of them, 191, did have something to say about the personal techniques they use to help avoid memory lapses.

NUMERICAL ANALYSIS.

This included responses to the demographic questions on the years the respondent had spent in ATC, the level of the facility, and his/her position. It also included their view on the importance of memory to ATC and three evaluation questions on the handbook itself: relevance, realism, and overall. Finally, there was a

question concerning whether or not the individual wanted more copies of the handbook.

A cross tabulation of the requests for additional copies by position in the facility was computed. Table 1 indicates the frequencies of responses for and against additional copies. There was a significant relationship between position and whether the individual wanted more copies (chi square = 23.63, $P < .01$). This demonstrated that the more senior the respondent, the more likely it was that he/she requested additional copies. This will be confirmed by some correlational data to be reported later. The range of copies requested was from 0 to 420, with a mean number requested of 20.11. There was a great deal of variability with a standard deviation of 59.8.

TABLE 1. CROSS-TABULATION OF REQUESTS AND POSITION

Position	Requests	
	Yes	No
Facility Manager	10	1
Other Managers	42	29
Full Performance	61	117
Developmental	12	12
Total	125	159

Data from the four rating scales in the questionnaire are summarized in figure 3 which provides the means or averages of the responses, and in figure 4 which shows the distribution of responses over the 10-point scales. The variability of responses across the four scales was remarkably consistent and is indicated by the standard deviations as reported in table 2.

The means and standard deviations are indicative of controller opinion concerning the importance of memory and the relevance of the controller handbook. The greatest level of agreement was on the memrole question having the smallest variability and the greatest mean. In fact, the most frequent response to the question or mode in statistical terms was a 10. The mode for the other three questions was a 7 for the overall evaluation of the handbook and an 8 for the relevance and realism questions.

An issue of concern was whether tower and center personnel would somehow differ in their ratings. Table 3 provides the means and standard deviations for these two facility types.

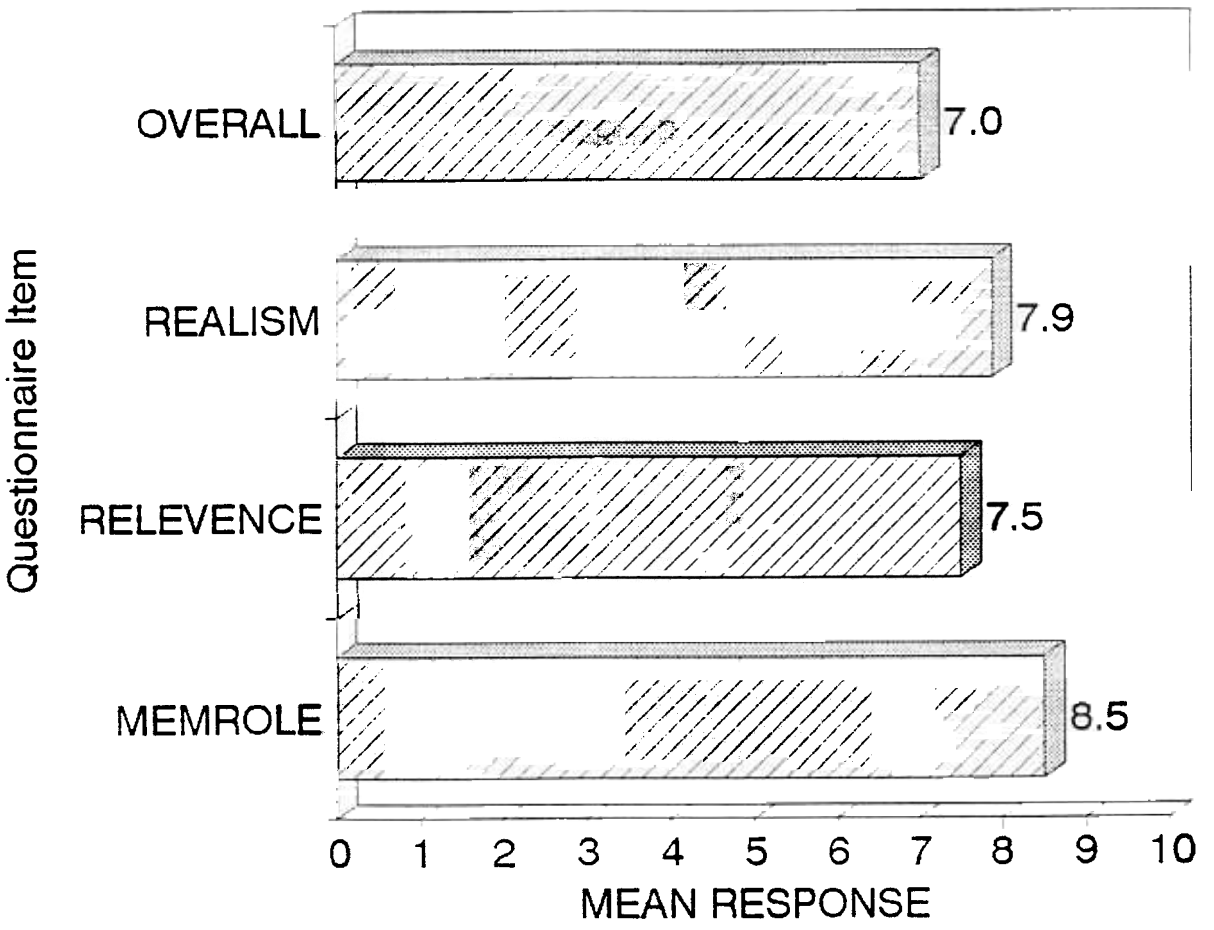


FIGURE 3. MEAN QUESTIONNAIRE RESPONSES

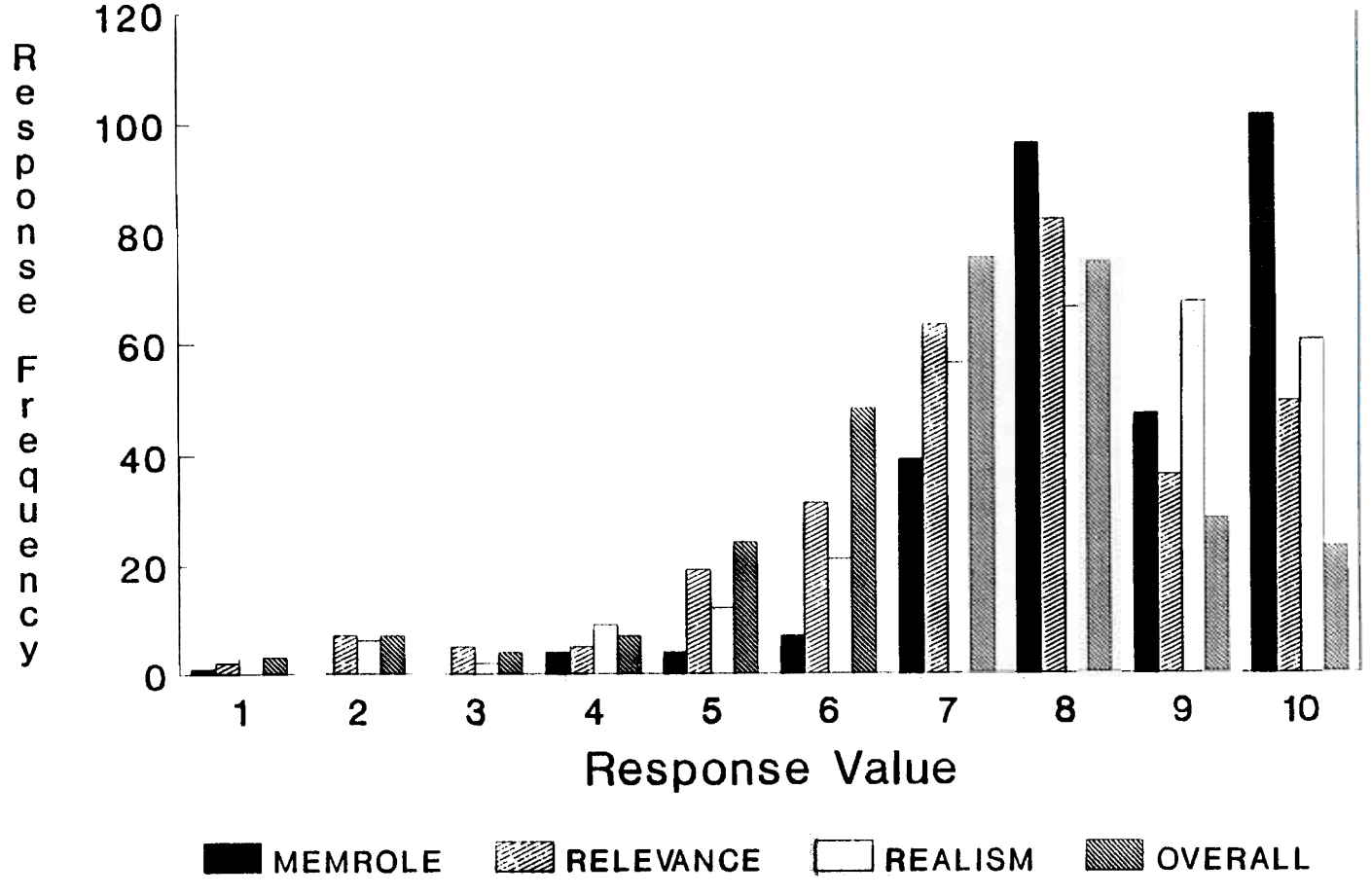


FIGURE 4. QUESTIONNAIRE RESPONSE DISTRIBUTIONS

TABLE 2. STANDARD DEVIATIONS OF SCALE RESPONSES

Scale	
Overall	
Realism	
Relevance	
Memrole	1.39

TABLE 3. MEAN RESPONSES BY FACILITY TYPE

Question	Towers		Centers	
	Mean	SD	Mean	SD
Memrole	8.66	1.28	8.41	1.50
Relevance	7.68	1.72	7.30	2.05
Realism	8.06	1.67	7.72	1.91
Overall	7.21	1.77	6.87	1.83

It might appear from an examination of this table that center controllers rate the handbook and the overall impact of memory slightly lower than do their colleagues in the tower facilities. In order to determine whether there was anything to this possibility, a series of one way analyses of variance (ANOVA) were computed. ANOVA examines the differences between the means such as 8.66 and 8.41 for the ratings of memrole and evaluates it in terms of the variability in each group along with estimates of the variability in the population of controllers. This allows for an inference of the probability that an apparent difference could have occurred beyond the level of chance. Results are reported as F values which must exceed a critical minimum to be significant at the $P < .05$ level.

The critical value for significance ($P < .05$) between center and tower controller responses was $F = 3.84$. As will be seen in table 4, none of the computed F values reached this magnitude. This demonstrates that for all practical purposes there were no systematic differences in the ratings made by the controllers from the two types of facilities.

TABLE 4. ANALYSIS OF VARIANCE ON TOWER-CENTER RESPONSES

Question	F Value
Memrole	2.46
Relevance	
Realism	
Overall	

An initial examination of the responses to the overall evaluation of the handbook indicated leaders tended to rate higher than controllers. For example, the lowest rating given by a facility manager (N=10) was a 7. However, chi-square analyses of tower and center responses, respectively, indicated no significant relationship between an individual's position in the facility and how he/she evaluated the overall quality of the handbook (tower chi square = 32.14, P>.05; center chi square = 7.18, P>.05).

The next step in the analysis of these data was to examine the relationships between all the variables of interest to determine the degree to which they covaried. Correlations were computed between all the question responses and several of the demographic variables. Correlations range from 1 to -1, and the closer one approaches either ene point the stronger is the relationship between the two variables. Table 5 summarizes the results of these computations. Correlations which are significant from zero are designated by an asterisk. This means simply that it is unlikely that the relationship occured by chance alone. It does not, however, imply that it is a strong relationship. With this sample size approaching 300 respondents, any correlation which exceeds r = .148 will be significant.

TABLE 5. INTER-CORRELATIONS OF QUESTIONNAIRE VARIABLES

	Years	Memrole	Relevance	Realism	Overall
Position	-.65*	-.06	-.05	-.13	-.11
Years		.11	.04	.12	.07
Memrole			.37*	.33*	.26*
Relevance				.72*	.65*
Realism					.64*

An examination of the table indicates that the strongest relationship present is between the position of the respondent

and the years he/she has been in ATC. The relationship is negative because of the way position was coded. The highest position, facility manager, was a 1, and the lowest, developmental controller, was a 4. So the interpretation of the -.65 is simply that the more years in ATC, the higher the position held. The results also indicated that the higher positions tended to rate the handbook's realism and overall quality a bit higher than did the rank and file controllers. This was not significant from zero and confirms the earlier reported results of the chi-square analysis that ratings were relatively independent of position held. The evaluation scales and the rating of the importance of memory all seemed to correlate to one degree or another with each other which led to the hypothesis that they were probably not orthogonal. In other words, some of the scales might be measuring basically the same thing. This would mean that if a respondent rated realism of the handbook as high or low, he or she would likely give a similar rating to the construct of relevance.

In order to evaluate this hypothesis more systematically than by scanning the correlation matrix, a factor analysis was computed. This statistical technique is designed to look for redundancy in a data matrix and determine whether the data could be explained or described by a more streamlined set of variables or factors. The software determines what factors or clusters of correlations exist. It then computes the factor loadings which are basically correlations of the original variables with the new variables, the factors. These are then named based on the variables that load on them.

A principle axis factor analysis was computed along with a verimax rotation, and the results are presented in table 6.

TABLE 6. QUESTIONNAIRE FACTOR ANALYSIS

Variable	Factor 1 Handbook Quality	Factor 2 Memory
Memrole	.155	.984
Relevance	.851	.272
Realism	.867	.210
Overall	.870	.085

The pattern of factor loadings is consistent with the belief that respondents rated the importance of the role of memory more independently from their ratings of the handbook than they did across the evaluation scales for the handbook. They were able to keep the two issues somewhat separate. Once they formed an opinion of the handbook, it was reflected in all three scales,

which basically measure what amounts to one variable, the controllers impression of handbook quality.

TEXT ANALYSIS.

There were two open ended questions in the survey. The first asked for the controllers responses concerning what they saw as the impact of memory on performance. The second question asked for any personal techniques that the controller might use or know about that could help others. These were the strategies that no operator can function without, although we are not always clear on how we use them. According to Vicente (1990), one can never fully understand the complexity of any job performance until you have a handle on the strategies the operators use to carry out the task. A large number of controllers had something to say on one or both of the impact and techniques issues. Their responses were sorted based on the type of facility they were in and whether or not they were managers.

This material was edited only from the perspective of trying to make it readable. In no case was it altered in terms of content and no attempt was made to make complete or technically grammatical sentences. The sorted responses are presented in total in appendix C of the report, and it is suggested that the reader take a few minutes and scan this data for both questions. Respondents had considerably more to say in terms of techniques than they did about impact. However, the reader will see some overlap in the responses based on how the controller interpreted the questions.

The question on impact was apparently interpreted in several ways. One interpretation centered on the factors which influence performance and memory. The majority of responses seem to go along with this approach. Another view of the question, and the one which was actually intended, was how memory lapses actually influenced performance. In terms of their text responses, very few controllers saw the question this way. However, the data do serve as a fund of information on what the controllers are concerned about in their work place that could negatively influence memory storage and recall.

The analysis of this material is admittedly subjective. The text strings were reviewed for both the frequency of any given response and for unique or salient responses that the investigator felt were worth calling to the reader's attention. Table 7, "Controllers' Views on Memory Impact" highlights some key areas that have appeared not only in this study but have also been seen in other reports such aviation safety reporting system (ASRS) documents. The potential for error based on inaccurate or hurried position relief briefings is noted. Too much work appears as well as too little. Several controllers commented on errors, presumably memory related, which occurred either during

TABLE 7. CONTROLLERS'S VIEWS ON MEMORY IMPACT

TOWER	CENTER
Leaders	**Leaders**
Position Relief Briefings	Attention
Coordination	Distraction
Errors during light Traffic	Tunnel Vision
Controllers	**Controllers**
Position Relief Briefings	Non-Routine
Fatigue	New Routes/Restrictions
Overload	Distractions
Changes in Procedures	Overload
Distraction	Change

periods of light workload or during transitions from low to higher workload. There appears to be greater emphasis by leaders in centers on the impact of loss of attention, distraction, and what the investigator is calling tunnel vision, implying a loss of attention based on over concentration in one area or task. A simple count of the responses indicates 119 controllers out of 299 questionnaires returned thought this question was important enough to answer. The fact that their responses are in line with other data sources adds credibility the rest of their answers in the questionnaire.

This survey effort had two main goals. One, of course, was the evaluation of the handbook and the second to try and learn more about the impact and management of memory as seen in the field facilities. An overview of the responses concerning controller memory techniques follows.

CONTROLLER MEMORY TECHNIQUES.

As with the impact question, this material was sorted by facility type, tower, and center, and by whether the respondent was currently a manager/leader or an on the boards controller. The 191 controllers who responded to this question provided a text data base of in excess of 2800 words which was considerably more information than appeared on the impact question of impact(1274 words). It was decided to handle this material differently. Again the reader is encouraged to go to appendix C and read the source material in its double spaced format.

The analysis of this material did not attempt to classify differences between facilities or status positions. The reader is free to attempt that task analytically. However, we see this as a preliminary data base from which we may be able to extract both common sense and conventional wisdom.

The process for achieving this began in a very low technology fashion. The author reviewed the material and using a yellow highlighter attempted to identify recurring key words without attempting to count them. Once identified, these key words became the headings of a taxonomy or classification system against which we could do some quantitative analysis. There were 191 responses to the techniques question and we were interested in the proportion or relative frequency of each of the key words or strings within the 191 responses. Using Norton Utilities software, a text search and tally was accomplished on 15 key words or strings. The frequency tallies were converted to relative frequencies or percentages by dividing them by 191 then multiplying the results by 100. Those words/strings which achieved a relative frequency of 4 or more (an arbitrary cut point) are graphed in Figure 5 "Controller 'Techniques' Content". Not shown in the graph are the following key words: "Repetition, checklist, association, chunk, and memory joggers." These words

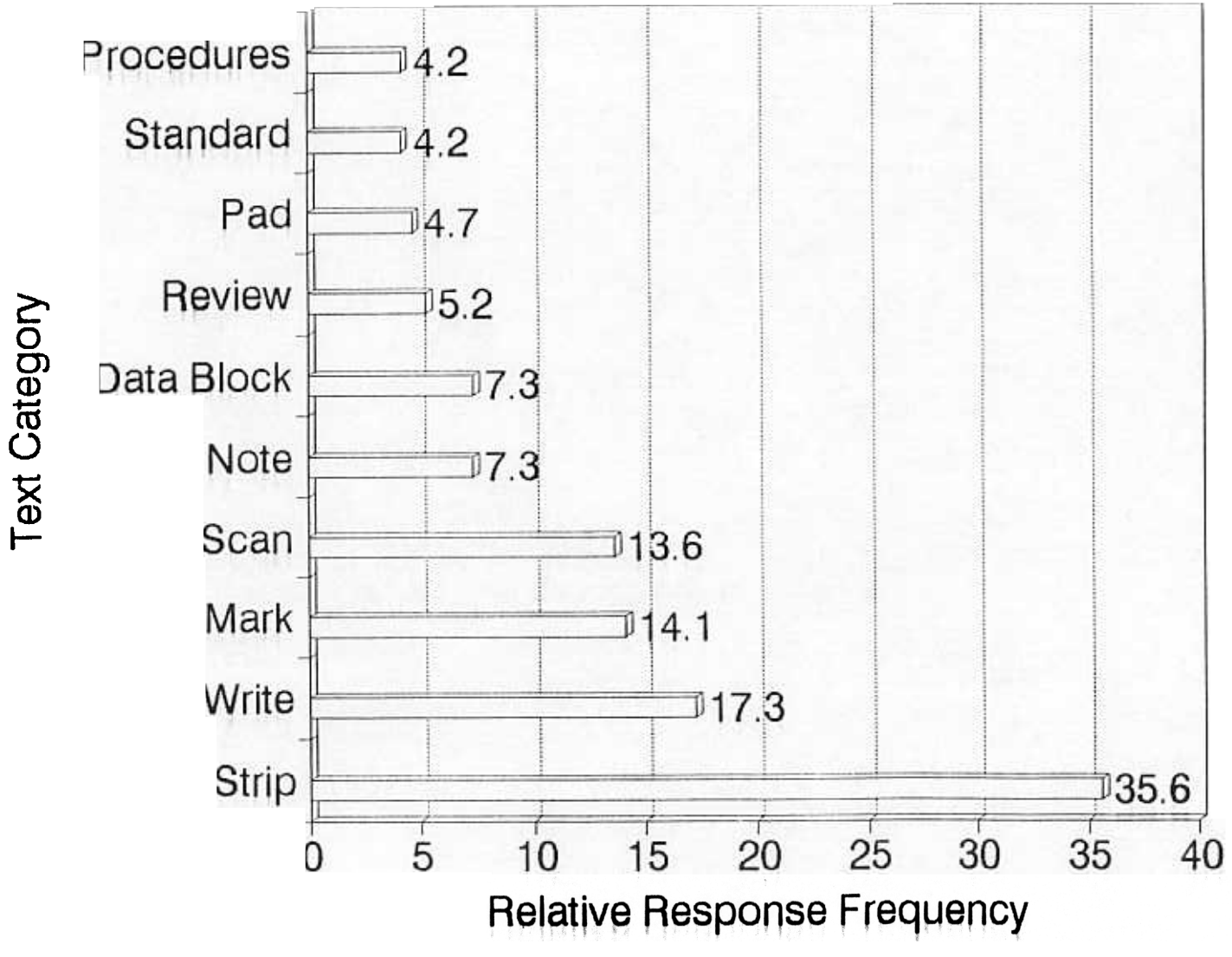


FIGURE 5. CONTROLLER "TECHNIQUES" CONTENT

These words appeared five to seven times in the text but achieved a relative frequency of less than 4 per cent. This is compared to the most frequently cited tool for the management of controller memory, the flight strip which appeared 68 times in text and achieved a relative frequency of 35.6 percent.

Figure 5 shows that the most frequently cited techniques for memory management are what might be viewed as very conventional methods, many of which are actively taught in training and are encouraged by operational procedures and management. Much of the emphasis in the responses to the techniques question is on what might be called system and method. This involves creating an environment in which tasks are accomplished in a consistent fashion with a focus on routine where possible, and on the use of support materials such as flight strips and a note pad where necessary. There is a general sense in the responses which may well have been driven by the material in the handbook that memory can be unreliable, especially when the operator is under load from multiple tasks. However, no technique or group of techniques is cited by the majority of controllers or by personnel within one of the four groups - leaders and controllers from towers and centers.

Controller personnel tend to be individualists and this is apparent in their responses. There is a great deal of variability in the way they say they approach the memory issue. Every controller adapts to the demands of the situation using techniques that work to one degree or another for him/her. One of the purposes of this study was to gather this information and provide it to personnel in the hope that an idea from one controller might be useful to someone else that had not thought of it. Reading the techniques in appendix C may, therefore, be useful to controllers and leaders alike. The less frequently cited methods which are not in the common domain may serve as a stimulus for new and experienced controllers alike. An example of this is the suggestion by one tower leader who said: "...Visualize the numbers as you speak, create a 3d minds eye and see in advance not just in the now time frame." A center leader proposed using the old but valid 3R learning method to improve memory. The 3R's refer to: read, review, recite - an active learning process.

One surprise in this text data was the frequency that controllers responses included references to visual scanning in their answers to the techniques question. Scanning was identified by the same Administrator's task force that viewed memory as a problem area for controller errors. One controller suggested that his specific experience as a pilot, where systematic scanning is actively taught, has helped him considerably in his control duties. It is likely that we will find that how controllers reach out for information may well have an impact on how well

they are able to organize, code, store, and subsequently retrieve that information in a timely and accurate basis.

DISCUSSION

Human memory will continue to be an elusive concept which is misunderstood and is often blamed when performance failures occur. We accepted for generations that we have limitations. Then we have driven on to exceed them, sometimes successfully and other times not. George Miller (1956) talked about the magic number 7 plus or minus 2 when he tried to identify the number of units of information humans could safely hang on to for a short period of time and successfully recall. We know today that we can handle more information if we manage it properly. However, for many intents and purposes our short term or working memory is very limited (Wickens and Flatch 1988). If we overload it, information will be lost at critical times. There is little knowledge available today concerning how memory influences the operators of high technology systems, and even less concerning the ATC system. MIL-STD-1472C (1981), which is often used to guide the development of systems for the U.S. Government, does not specify clear criteria for memory demands on an operator. It only suggests that they be minimized.

The Controller Memory Handbook was developed in response to numerous suggestions from the field environment that memory lapses were a problem that needed some attention. The FAA organized an advisory group which formally identified the problem, and eventually a program was begun at the FAA Technical Center. The purpose of the handbook was to produce a job aid for field controllers in the here and now. It was written based on what is currently known about human memory and how that fit within the context of ATC. Enough copies were printed for a limited experimental circulation to centers and tower/TRACONS. This was seen as a opportunity to do two things: (1) ask current controllers what they thought about the handbook and (2) gather their input concerning how memory influenced their jobs and what they did to cope with it.

A traditional return rate for a mail away survey is between 10 and 30 percent. Air traffic controllers in the sampled facilities returned a much higher number of questionnaires than was anticipated. This was viewed as an indication of their interest and of their concern about memory in ATC operations. In one facility the controllers were so eager to have their input recorded, they made additional copies and actually sent in more responses than they received questionnaires.

The majority of responses came from high activity facilities. This does not signify more interest at such operations because the response rate is confounded by the fact that there are simply more controllers at the level 5 towers and at the centers. Those

responding had a considerable breadth of experience which averaged in excess of 14 years.

One item in the questionnaire asked whether the respondent wanted additional copies of the handbook. There was a clear relationship between where the individual stood in the management hierarchy and whether or not he/she asked for more copies. Managers were more likely to ask than nonmanagers. This makes sense from the viewpoint that management is responsible for the training of their personnel while the respondent controller already has a handbook and could not see a need for additional copies.

Controller ratings of the role of memory and of the handbook indicated that, in general, they felt that memory was an important element of their work life and that they liked the handbook. The agreement level was higher concerning the importance of memory than it was on the handbook itself. While most of those responding felt that the handbook was a positive contribution, there those who simply did not like it. Some felt it was too simplistic and others indicated that the cartoon format was inappropriate for the purpose. However, the reading level, the content and the format were all designed with the express purpose of catching the controllers attention and holding it for about 10 minutes of off-duty time. This is not a simple task, and given the response rate and the nature of the ratings, it appears to have been successful.

There were no basic differences in the rating responses between the tower and center respondents. The handbook was designed as a generic product and seems to have achieved the goal. Further, ratings of overall quality were unrelated to the position held in the facility indicating that the ratings were not significantly influenced by social status. The results of the factor analysis indicated that raters were actually evaluating two relatively independent dimensions: the quality of the handbook and the importance of memory in ATC. This meant that a respondent could like or dislike the handbook and still accept the importance of human memory for working traffic.

This brings the discussion to the analysis of the text material provided by the majority of respondents. The fact that so many controllers took the time to write in answers to the open ended questions is significant in and of itself. Often survey respondents will leave such questions blank. This could be viewed as an additional indicator that field controllers feel that memory is an issue with which they need to be concerned.

The first question on the impact of memory on ATC was misinterpreted by the majority of respondents. The purpose of the question was to determine how memory influenced performance. The controllers interpreted it to mean what factors influenced

memory and performance. This is the author's responsibility in that the intent of the question must not have been sufficiently clear. However, the data which resulted was still worth having. It demonstrated that controllers concerns center on many of the same issues that have continued to surface in work groups and in the literature surrounding operational errors. Over one-third of the responding controllers had something to say on this topic. The key points of their concerns were summarized in table 7 of the "Results" section.

When asked how they managed to cope with their memory limitations respondents had a great deal to say. There were some unique and many techniques which were cited by over 4 percent of the sample. The common thread of the techniques cited most frequently could be summarized by two simple words: "**good housekeeping.**" The most common tools that controllers feel work for them are those basic procedures and aides that are described in the controller's manual and are taught in training: writing things down, using the flight strips the way they were designed for, following procedures, and keeping alert by scanning the displays. It was not surprising that, in general, there were no magic bullets or instant solutions. The general conclusion that may be drawn from the this material is that the solution to memory lapses is in a professional workmanlike attitude coupled with the consistent use of tools that are available in today's technological environment. This involves an emphasis in training on the advantages of the techniques that may be avoided as confidence builds with experience. It also involves the necessity for leadership which follows up and continues to teach the importance of using the procedures and techniques that minimize the likelihood of the response: "I Forgot!"

BIBLIOGRAPHY

Department of Defense (1981, May), Military standard human engineering design criteria for military systems, equipment and facilities, MIL-STD 1472C, U.S. Government Printing Office: Washington, DC.

Finklman, J. M. and Kirchner, C. (1980), An information processing interpretation of air traffic control stress, Human Factors, 22(5), 561-567.

Kirchner, J. H. and Laurig, W. (1971), The human operator in air traffic control, Ergonomics, 14(5), 549-556.

Lorayne, H. and Lucas, J. 1974), The Memory book, New York: Ballantine.

Operational Error Analysis Work Group (1987, August), Actions to implement recommendations of April 17, 1987, Unpublished manuscript, Federal Aviation Administration, Washington DC.

Miller, G. (1956) The magic number seven plus or minus two: some limits on our capacity for processing information. Psychological Review, 63, 81-97.

Rasmussen, J. (1988, July), Information technology: a challenge to the human factors society. Human Factors Society Bulletin, 31(7), 1-3.

Spettel, C. M. and Liebert, R. M. (1986), Training for safety in automated person machine systems, American Psychologist, 41(5), 545-550.

Sperunido, J. M. (1971), Variations of operator's strategies in regulating the effects of workload, Ergonomics, 14(5), 571-577.

Stein, E. S. and Bailey, Jim (1989), The controller memory handbook, DOT/FAA/CT-TN89/58, Atlantic City: DOT/FAA Technical Center.

Thomas, D. D. (1985, October-December), ATC in transition, 1956-1963, Journal of ATC, 30-38.

Warm, J. S. and Dember, W. M. (1986, April), Awake at the switch, Psychology Today, 20(4), 46-53.

Vicente, K. J. (1990, November), A few applications of an ecological approach to human factors, Human Factors Society Bulletin, 33(11), 1-4.

Wickens, C. D. and Flach, J. M. (1988), Information processing, In E. L. Weiner and D. C. Nagel(eds.), Human Factors in Aviation, New York: Academic Press.

APPENDIX A

FACILITY LETTER

ACD 340
March 12, 1990

Facility Manager

Dear sir,

The Technical Center has a program, which is sponsored by the Federal Air Surgeon, to search for alternatives to help controllers make better use of their memory resources. This program titled "Controller Memory Enhancement" is focused on what we can do today with what we have now to reduce the probability of memory lapses and subsequent errors.

As part of this program we have developed the Controller Memory Handbook, copies of which are enclosed. This is aimed primarily at new controllers, but we hope that it is written in a style and format that everyone would want to pick it up and leaf through it. It employs cartoons and humor to present some basic concepts of human memory that many of us take for granted. It is designed to get people thinking about how they depend on their memories during their job performance and how memory can be troublesome if not used efficiently. Obviously, this booklet can not solve all our operational problems; it is just a first step. The copies I have sent you are experimental, and the reason that I am writing is to ask for your help. I am enclosing 10 copies of a questionnaire and would very much appreciate it if you would ask some of your people to examine the handbook and voluntarily complete the questionnaire. I am looking for ideas and opinions from the entire range of controller experience, from developmental controllers to supervisory personnel. Participants could mail the questionnaires directly back to me or you could send them as a batch. I would be happy to provide you with a summary of your facility's responses(without individuals names attached) if you so desire. The Handbook has been cleared for this circulation through AAT 14 ATS Training Requirements(Mr Charlie Parks FTS 267-9208). AT-1, Mr Bill Pollard, has received a personal copy.

I would very much appreciate your help in obtaining this feedback on the handbook and any additional ideas you and your personnel have on what we can do to reduce memory lapses(see the second page of the questionnaire). Please feel free to reproduce the questionnaire if you have more people who want to respond. If you have any questions you can call me at any time at FTS 482- 6389. Thank you very much for your cooperation.

Earl S Stein Ph. D.
Eng. Res.Psychologist

APPENDIX B

QUESTIONNAIRE

CONTROLLER MEMORY HANDBOOK
RESPONDENT QUESTIONNAIRE

This handbook has been developed as an aide for controllers in order to help you avoid errors which may result from inaccurate or inefficient use of your memory resources. The handbook was written by an engineering research psychologist and an air traffic controller, neither of whom would pretend to have all the answers. We would appreciate your input so that our future efforts can be even better. Please take a few minutes and respond to the questions below as accurately as you can. Once your responses reach the FAA Technical Center, they will be treated as confidential. However, if you wish, you may leave blank any items with which you have a problem. Thank you for your participation.

Name:_____ Facility_____

Your Position_____ Your Years in ATC_____

Your Facility Level 1 2 3 4 5 (Circle one)

The Date Today is

1. Circle the number below which best reflects the degree to which human memory plays a role in the performance of air traffic controllers at your facility.

(Very little) 1 2 3 4 5 6 7 8 9 10 (Very Much)

2. After reading the Controller Memory Handbook, circle the number below which best describes the relevance of the material to what happens in your facility on a daily basis. (Are we in the right ball park?)

(Not Relevant) 1 2 3 4 5 6 7 8 9 10 (Very Relevant)

3. Please circle the number below which best describes your level of agreement with the statement: "The problems described in the handbook are realistic in terms of what happens in air traffic control."

(Strongly Disagree) 1 2 3 4 5 6 7 8 9 10 (Strongly Agree)

Below would you list any areas in air traffic control which are or

may be impacted by memory lapses and which we did not cover in the handbook. If you are not sure list any ideas you have anyway. There are no wrong answers to this question.

_____

_____

_____

Use additional sheets if you need more space

5. Do you have any personal techniques which you or another controller developed for your own use to help you maintain the picture and not forget important details. Please list them below.

_____

_____

_____

6. On the scale which follows would you circle the number which best reflects your overall evaluation of the quality of the Controller Memory handbook.

(Very Poor) 1 2 3 4 5 6 7 8 9 10 (Very Good)

7. If you could have additional copies of the Controller Memory Handbook for your facility, would you like them.

Yes

If yes, How many copies?_____

(Note: This question is for planning purposes)

You may call the author at FTS 482- 6389 if you have any questions or comments that will not wait until the questionnaire reaches the author. Thank you again for your participation.

Instructions for administration: Please see that the completed questionnaires are returned through whatever channels have been explained to you. The final destination for the completed questionnaires is as follows:

Dr. Earl Stein
DOT/FAA Technical Center
ACD-340
Atlantic City International Airport
New Jersey 08405

Please mail directly if the questionnaire was not group administered.

APPENDIX C

TEXT DATA

RESPONSES ON TECHNIQUES FOR MEMORY MANAGEMENT

Tower Leaders Personal Techniques for Memory Enhancement.

Avoid distraction excess during slow periods

Use of special marked strips, i.e., "Car on the runway, "RWY 7L closed," underline certain information that needs to be remembered, checks or special marks beside info to draw attention.

Adhere to procedures and do not deviate. Use caution with improvisation. Teach all developmentals and FPLS to do it the same way all the time.

Write what you say. Read what you have written at readback

Mental exercises to keep motivated. Ability to play chess. Plan ahead rather than be reactive after the fact, i.e., checkers.

Flight strips are grouped in categories: arrival, departure, overflights.

Write down call sign when a/c calls, check it when cleared to land, cross it out when we send to ground.

Have personally tried techniques in the handbook, i.e., writing things down on a strip or pad such as altitudes and headings and checking on receipt of a pilot readback along with leaving problems at home.

One of best techniques is attentive listening. Make sure I heard what I heard.

Sit upright in the chair or stand. Relaxed position tends to allow memory lapses.

Write it down. Do the same thing with each aircraft

Annotate using personally designed marks on strips or paper

Annotate with call signs to jog memory on uncompleted actions.

Alliteration is often helpful. Acronyms also!

Detailed strip marking including headings and altitudes. Include information even if not required by the facility.

Strip marking and standard operating procedures.

Issue an instruction to an a/c and make a mental note of next step with that a/c. Then on the next #5 visual scan when I return to the a/c, I already know what to do.

Association. Picture something in your mind that you can relate to a name, number, etc. Repeating something you read or hear often helps with memory.

Regurgitate the information in your mind a couple of times until you remember it.

Learning and using proper procedures. You can always fall back on good habits and use strip marking for immediate reference.

Scanning techniques from pilot experience. Periodic review of information, rules, etc.

Organization and consistency are the keys to selective memory.

"Getting a flow." This helps getting a scan established.

Association, repetition, strip marking, cocking strips, notes, checklists. Remain at position to insure the relief has the picture.

Review the traffic constantly and try to stay one step ahead.

Keep notes on anything out of the ordinary. Do not allow self to get overloaded.

Standard patterns, scanning from farthest to closest point, correlating scan to strips, and initiation handoff when transferring control.

Don't rely on your feeble memory. Use strips and write it down.

Focus on essential data, last 3 digits in call sign, major elements in the call sign, etc.

Effective use of position checklist.

Pad marking, checklists, standard strip marking, ATIS codes

Before ARTS had to train on strip-target coordination. Train self for short term memory retention of one-half hour or so.

Scratch pad written notes.

Turn off ARTS occasionally and develop memory through practice. Controllers depend totally on the computer.

Simulation and rhymes.

Flight strips arrangement and marking.

Use strips to the maximum extent possible. Develop some time procedures for yourself. Things you do the same way for each arrival/depart. Don't rely on your memory, check and recheck, confirm and reconfirm.

Mark strips in red in the sequence bay. A local control to remind us of vehicles on the runway. When an aircraft cleared for t/o or landing, pull strip out of holder about 2 inches as a reminder.

Keep things simple and repetitive.

Look at appropriate data during clearance readback: alt beacon.

Relate to the numbers you know well, i.e., addresses, phone numbers, visualize the numbers as you speak, create a 3d "minds eye," see in advance not just in the now time frame.

Use strip management more than dependence on the ARTS to manage my traffic.

Never have more than one potential conflict going at once Use the stubby pencil the same way all the time. No distractions.

Avoid issuing altitude and heading change in the same transmission during busy periods.

Maintain proficiency on all positions

<u>Center Leaders Techniques for Managing Memory.</u>

Grease pencil notes on scope or blank strip.

Constant scanning. What is it doing? What do I have to do?

Carry a small note book with information not used every day.

Use pencil. This says it

Think standard operating techniques and standard sector procedures.

Scan strips to identify any errors that need action. Determine if action required is immediate, short term, or long term. Scan clock 3-4 times/minute and at times on strips to alert to any action needed.

Work in an organized manner. Radar blocks offset to reflect the next fix such as 9 o'clock offset southbound, 3 o'clock for east or southeast bound. Write it down.

Writing the information as you talk and repeating the information as a cross check.

Write it down.

Keep records on all ATC functions. Do not rely on memory. Use repetition.

Ask the other controller on the sector to remind you of what ever you commonly forget.

Write it down!! Either on the scope on the strip or on the scratch pad. It depends on the situation involved.

Maintain a definite scan pattern and constantly repeat it so as not to miss anything. Sometimes you need to force yourself to scan in a constant manner.

Scan. Being an ex-military pilot, I find constant scan techniques excellent.

Tilt strip holders.

Use positions of data blocks for some information. (Chunking)
Cocking strips in the bay for some needed actions.

Data block positioning to indicate direction of traffic flow immediately presents a pictorial traffic scenario without having to constantly reread strips.

Marking strips when you talk to aircraft. Do not check alt level until a/c actually reports in. After switching a/c shorten the data block.

Awareness, project what will happen and consider alternatives.

Use a learning process developed by the Air Force called the 3R method. It could be helpful to controllers in memorizing data.

Remember possible conflicts and what quadrant they are in. Add and subtract from this picture.

Write it, if it is important. Use status information areas. Use visual strip board at VFR tower where there is no Brite.

Slant data tags after frequency transfer. Start data tags on inter-facility point outs.

Preplanning action aids. Developing an efficient operation. Staying current on procedures.

Correlate information transmitted and received visually with the progress strip.

Keep eyes moving and look for trouble even if going good.

Direct routes changes the picture when approved.

Tower Controllers Personal Techniques for Managing Memory.

Relax.

Repetition and evaluation of past experiences.

Checklists, establish routines, visual scanning, visual aides, i.e., lights and strips, sharing information with coworkers for checks and balances.

Strip bay organization.

Listening and memory go hand in hand. ATC memory is a tool that is acquired by actually doing the job. Tune up listening skills.

Write the numbers and recall what the requests were, then act.

Write things down over and over.

Use the ARTS to full extent to keep up and keep eyes on traffic.

Scanning and review.

Grouping flight control strips together by destination, category (overflights, arrivals, departures), type (IFR, VFR). Cocking strips, compulsory reporting points or altitudes.

Group aircraft together. Have one follow the other. Minimize individual control actions.

Sequencing of information. Not only chunking but maintaining an order of information, i.e., HDG, ALT, etc. Giving runway assignment at a certain point. Develop strip marking for own memory limitations.

Strip marking, handwritten notes and "IDS" entries. Write it down. Keep mentally reviewing or rehearsing, Listen!

Write big on strips and put it in front of you. Put your pen on a primary.

Constantly review the scope or area of control looking for anything not ordinary.

Use association as an aid. Group things I need with words or objects.

I pretty much use the same techniques stated in the handbook.

Ask trainee secondary memory questions to refresh myself

Write down information instead of trying to remember

Reduce tasks. Listen attentively, prioritize, take notes.

Use ARTS functions as reminders, i.e., handoff to appropriate position note pad, 7th field character, leader line direction for runway.

Count strips, count aircraft, scanning.

Using an ARTS symbol over uncontrolled airport to indicate release of IFR traffic.

Memory joggers. Prefer video tape instruction to handbooks.

Strip marking and keep it up to date to fall back on. If an a/c is holding between runways, circle the aid to draw attention.

Put x on strip of an active runway when clearing a/c crossing.

Visual aides such as cocking a strip when a/c are holding short or cleared for takeoff.

Comp procedures strictly enforced. Accurate strip marking. Strip placement.

Strip management. Not adequately taught in training.

Work within ability, standardize operating procedures

The pad is essential to professional performance at level 2 towers and probably level 3, and it is also mandatory.

Write everything down as much as possible. Notes serve as memory joggers.

Good scanning technique to constantly update information. Write it down.

Leave non-ATC matters outside. Prepare your mind to work. Keep scanning. Complaisance or paring your memory during light work load is trouble.

Establish key reference points - memory joggers.

Use the method described as chunking.

Scanning and association.

Know where to find answers to questions that arise
Example: Where is the approach plate?

Constant silent reiteration of sequence and inbound traffic is a constant process. Allows for continuous update and clump of old info.

Move the conflict alert display to an uncontrolled airport when IFR aircraft is released.

Circle important or different information. Place important information in a conspicuous position.

Use strip with point out on it, write things down, additional info like fix altitude, weather, and special coordination.

Write every change on strips except headings when vectoring.

Tape on palm of hand to indicate vehicle on active runway

Use check marks whenever an instruction is given. When busy, look at the flight strip to verify something.

Never give pilots more than 2 pieces of data at one time.

It is often advantageous to make multiple transmissions.

Reduce memory requirements especially nonstandard operations when busy. Try to complete a task and not leave it for later.

If anything is not routine write it down. Keep ARTS up to date.

Let other controllers know what you are doing. Constant review of material.

Relaxation methods help. The mind stops functioning when the mind is stressed.

Standard headings and speeds in similar situations. Chunking. Use memory joggers and scanning.

Memory joggers such as check marks, placement of strips, and scanning the scope.

Constant scanning of traffic pattern, scope, strips, etc.

Personal notation memory joggers.

Write down all a/c call signs and type. Have a method for marking each unique situation, i.e., a/c in position and hold, low approaches, touch and goes, helicopters, etc.

Write it down on strip or pad

Cocking strips.

Rhyme items to be memorized

<u>Center Controllers Techniques for Managing Memory.</u>

Arrangement of data blocks for landing traffic or traffic that must be sequenced. Write everything down.

Write it down and review the notes periodically.

Attempt one task at a time then move on. Don't be too eager to grant pilot requests when workload is heavy. Flag unusual routes or other oddities. Don't assume you will remember.

Pictorial imagination processes.

Continually employing complete and correct strip marking.

Always have a note pad for other bits of relevant information.

If busy, concentrate or remember a problem or potential problem and watch it closer than the others.

Strip marking.

Develop and exercise routines, listen carefully, and write things on strips or scope.

Listen to readbacks and mark strips. Combined with the original clearance, this makes three times you see or hear a clearance.

Visualize what the a/c is doing when he first calls in: call sign, visualize the plane, altitude, climbing, descending, level, route, visualize across the scope, visualize potential traffic.

Positive repetition aids retention. Process the "blocks" the same as much as possible. Develop a checklist for yourself. continue to run through it even when it is slow. By using the same format it is easier to spot mistakes.

The shortening of data blocks after switching an a/c to another frequency.

Before controllers can improve they must want to improve. They need the desire and the "passion" for aviation.

Position the data blocks south for traffic going to Florida and north for traffic going to Atlanta.

Make up phrases, enhance information on the strip

Write things down as you speak.

Try to avoid "stress recall" (something that has to be said immediately).

Blocking weather into a category (i.e., IFR, VFR, MVFR). Mentally flying each plane through the sector to get a good and updated picture.

When not too busy, try to look away from the scope or close eyes for 5 to 10 seconds and mentally picture who each aircraft is, what type, what alt, and where he is going.

Checklist of priorities.

Information repetition.

Put interim alt in data block after handoff before he is shipped to me so I see that the a/c is clear. Use the /# feature to remind that something is to be done.

For an a/c descending per LOA, put the altitude in hard that will need to be assigned later. The current alt is listed as

an interim. The "T" will be in the data block as a reminder.

Scanning the PVD in an organized way looking at each a/c.

Preplan in red on the flight progress strips so as to not forget actions when the aircraft comes into control.

7110.65 items that aren't used everyday, approach plates. Note pad, write on the scope with grease pencil.

Review the flight strip and reaffirm in memory the a/c type and route of flight including the destination. Keep ahead of the workload.

Use mnemonics in applying reference information for certain control situations and for recall of information which is least often used.

Speech rate, speak at a methodical pace, do not rush then get irritated because you have to repeat. Chunk the traffic flow. "QU" irregular flights. Constantly scan for same altitudes and routes.

Grease pencil on PVD 5 mile polygon, vary leader length on PVD. Cocking strips and preplanning in red.

Make plenty of notes.

Data block positions, i.e., chunking.

Association.

Do a rapid screen then a strip scan. When an a/c calls, focus attention, take care of the request then revert back to the scan.

Placement of data blocks reference of actual targets, i.e., on eastbound traffic use positions 1, 2, or 3 for SE, E, or NE, respectively.

Cocked strips to reflect some coordination needs to be made.

The leader length on data blocks to show that communication change has been made. Plus and minus on various speed restrictions, i.e., -.80 a/c reduced to .8 mack.

Continuously scan scope and read call signs and altitudes.

Using correct altitude for direction of flight eliminates most head on situations. Simplify the traffic. Go back to basics. Solve problems now, you may forget later.

Control traffic like a defensive driver. Assume the next car will pull out in front.

Understand the usual fully so you can concentrate on the unusual.

Memory joggers strip marking, keep ready refer material current, play ATC trivial pursuit with others.

Use clearances that occur at the same point if possible. Try to make clearances, frequency changes, handoffs at the same point if feasible.

Proper strip marking, board management, keeping data block up-dated, will reduce the memory factor to almost nil.

Strip marking focusing on the vectored or conflicting situations.

Know when to call for help when there is too much traffic.

Preplan using computer updates. For an a/c descent, put the correct altitude in the "T" format to remind that it needs to be started down.

Always use every backup to memory available. Keep strip marking up to date. Keep data blocks updated.

Always review the strips when time permits. This especially helps in a nonradar environment.

Cocking strips, preplanning on strips by writing in red.

Give self a pep talk to be more alert and to get through the day without an error or incident.

Properly mark the flight strips and have the other information needed such as NAVAID, frequency, and radar outages.

More experience

Use word association to remember short term as well as long term memory items.

Making the information interesting and using it.

Write everything down. Work on speed to sort out the non-pertinent items.

Write study material down for long term memory.

When something is important add it to the memory list until there is time to go back and do it. Limit the list to no more than three things at one given time.

Review strip just prior to taking handoff to know type a/c, equipment suffix and route of flight, take the handoff and repeat key items silently to self.

Way of placing data blocks on the scope, i.e., eastbound put on the right.

RESPONSES ON THE IMPACT OF MEMORY

Tower Leaders View of the Impact of Memory.

Position relief briefing.

Moving traffic rapidly and forgetting only momentarily what is next or who is next.

EDCT releases.

Attention to duty should be more strongly addressed.

Check lists, sunsets/sunrise, lights, STEPS, visibility requirements, strip movements, handoffs.

Appears to be a most complete doc. The best I have seen.

Breaks from position. 2 hours are remembered better than after break.

Establishing proper prioritization of activities. ATCS actions.

Position relief briefings.

separation of aircraft

Position relief briefings.

Good percentage of errors occur during light traffic. How do you maintain your alertness when there is little to do and the mind tends to wander.

Amount of administrative and operational changes is confusing at times.

Position relief briefings. Review previously memorized material.

Coordination.

Not sure that controllers should rely on memory.

Assuming tower traffic pads

and computers eliminate some need but not all.

Control instructions, weptner pptd, a/c call signs, seldom used frequencies.

Frequency and altitude changes.

Position relief checklist

Information needs to be retained longer than normal period, i.e., vehicle on runways for extended period.

Remembering the sequence for pattern traffic when you have a large amount of pattern traffic.

Problems with spouse, kids, money, phone calls at work about it.

To replan you must remember the original plan. We have removed the need for memory with advanced alpha numerics and that is our loss.

1. Coordination. 2. Potential conflicts if no action is taken. 3. Situations that bear watching for future conflicts.

Details and aircraft under control during a change in airport landing direction.

Center Leaders View of the Impact of Memory.

Age and memory.

Air refueling and verbal relay of information. Restricted areas, NAVAID outages or frequency problems. Information on the flight conditions in the sector.

Loss of attention due to stress or emphasis on the good life, i.e., talking about an upcoming golf game.

"I'll stop him if necessary!" Then attention is diverted to another area of the radar and you forget to come back.

Highlight areas (sentences, words) in reference materials forneed to know, nice to know, and/or general information or background.

APCH and DEPT procedures and restrictions. Alt assignments, routings, responding to past requests. Preoccupation with one traffic situation and forgetting another.

Intense concentration on one area of focus can divert normal memory responses. To recover, note learning is a big plus. Not to rely on memory but to react from training so as to recover acceptably.

Forgetting work schedules.

All areas are impacted.

Seldom used special procedures. Rules and regulations covering administrative areas.

Inter-facility point outs, repeating clearances.

Preoccupation

Use established routes and confliction points.

Tower Controllers View of the Impact of Memory.

Work schedules.

Memory is as important in VFR tower as in approach control.

Distractions in the work place, i.e., another controller talking.

Aircraft call one after another. We get behind if we have to call each of them back and ask them what they want.

Radar or computer outage.

Age seems to be the biggest factor in memory loss.

Nonrelated external stimuli detract from memory.

Aircraft landing on other than normal runway. Write an "L" near the call sign.

As boundaries limit flow - must remember when release as to other.

All coordinations, using the pencil may be the best answer.

Remembering you have a primary and what you have approved, i.e., nonradar and satellite departures.

Boredom during slow periods of traffic when mind may wander.

Memory lapses from secondary long term memory lapses

Anything different from norm, i.e., different alt or runway.

Position relief briefings.

A/C left holding. Forgetting to cancel airspace block for completed approach

Tell new controllers what info is important-rarely done.

Management (a single response - no change).

Too much input at one time. Fatigue and days when you don't call in sick but are not feeling your best. Background noise.

Runaway incursions especially with airport vehicles on Rwy.

Stress, fatigue, memory overload.

Ego, pride, and appearance override sensibility.

Getting distracted by traffic complexity or volume and forgetting about a primary target (no transponder).

Relief briefings - info forgotten and not passed on.

The cog, the airplane, or situation that doesn't fit your organization or plan. Organization is good but flexibility is a must.

Constant changes, loss of memory with age.

Headings, altitudes, speed, coordination with other ATCS's or facilities.

Extra or required information may be omitted. Become too busy and leads to just separate the airplanes by issueing headings and altitudes only.

Fatigue, long hours on position, overtime

Pilots have limitations in memory also. Controllers should be aware of this.

Partially completed operations, i.e., strip marking, must completed later.

Assuming you heard something you didn't hear. Not listening.

Constant changing procedures, LOAS, LOPS, iter/intra facility, age.

Concentration vs distraction.

Using ARTS do not remember as well, depend on ARTS.

When a second controller tries to run your traffic.

Review procedures and new material until committed to memory.

Position relief briefing. Relieved controller should stand by.

Briefing materials and position briefings

Center Controllers Views on the Impact of Memory Lapses.

Information that is not used on a daily basis, i.e., warning areas special use airplace.

Coordinated information from other controllers during peaks, i.e., speed, headings, routes. Not adequately listening.

Airspace peculiarities and oddities.

Heading aircraft assigned. Reroutes not given.

When busy outside conversations can cause a memory lapse or loss of concentration.

A lot of information comes in at the same time making it harder to be systematic.

Flow control restrictions.

Forgetting which way an a/c is going when workload suddenly increases.

Letters of agreement and preferential routes.

PIREPS.

At end of mid-shift when exhausted, one tends to forget details specifically on the position relief briefing and departure clearances.

Supervisors, trackers, coordinators.

Procedures which are used seldomly tend to be forgotten.

Memory lapses may impact all areas of air traffic control.

New frequencies, nondaily restrictions, route changes due to filed bad routings.

Read back errors

Airspace altitude shelves and frequencies.

Long term memory may need to be refreshed so it is not forgotten and so awareness may be highlighed.

Almost all areas are impacted by memory lapses.

Call signs for VFR/IFR pop-ups are different to recall Unusual routes are also difficult to recall.

You can't remember pertinent information lie speeds, headings, requests, etc., with all the other distractions.

Stress the importance of strip marking.

The impact of distractions on short term memory.

Status of military restricted/released airspace.

Situation not used frequently such as nondiscreet codes. New procedures or letters.

Memory when it comes to tactics can sometimes be unhelpful.

When a radar controller gets too busy to accurately sequence strips and can not keep up with a radar screen scan followed by a strip scan.

Constantly changing procedures, LOAS, frequencies.

Short term memory on frequent changes is a big problem. Pilots contribute by forgetting to listen.

Keep it simple sir KISS.

Towers in busy facilities would seem to cause most errors.

Attention span

Changes in LOAS are sometimes too frequent and do not allow proper memory processes to take place.

Adjustment from periods of slow traffic to extremely busy conditions. Controller must recall a lot of information suddenly.

Expectation that this will happen is important.

Overload with too many a/c.

Daily flow restriction - when you are busy you forget to do these. Regulations that you signed off on two years ago and they expect you to remember.

Information from AIM and 7110.65.

Forgetting what is on the strip such as type and destination.

When you are busy it is difficult to keep looking

☆U.S. GOVERNMENT PRINTING OFFICE: 1991 - 504-061/40026